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PROBABILITIES FOR PERIODS WITH LOW WIND SPEED IN DIGERNESSUNDET

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SAMMENDRAG

The report contains a probability analysis based on data from the weather stations Sola and Flesland, 1957-1985. The probability for a 3 days period that have a maximum 10 minute wind speed not exceeding 5 ms^{-1} the first day and not exceeding 10 ms^{-1} during the following two days are determined.
At Digersundet the probability is calculated to 0.16, 0.14, 0.17, 0.25 and 0.19 for the months November, December, ..., March. The whole winter mean value is rather unprecise, but in February the probability is significantly higher (1% level) and December significantly lower (3% level) than the mean value.

UNDERSKRIFT

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SAKSBEHANDLERE

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S U M M A R Y

This report contains a probability analysis based on wind data from the weather stations Sola and Flesland, 1957 - 1985. The probability for a 3 days period that have a maximum 10 minute wind speed, FX, not exceeding 5 ms^{-1} the first day and not exceeding 10 ms^{-1} during the following two days are determined at both stations. Due to the wind speeds given in Beaufort, B, before 1982, we use $\leq$3B, and $\leq$5B as criteria. The upper limits then are strictly spoken 5.1 ms^{-1} and 10.8 ms^{-1}.

In the winter season the average probability for such events is calculated to 0.16, 0.13, 0.17, 0.27, and 0.17 at Sola in November, December,..., March with a mean value of 0.18. At Flesland the corresponding values are 0.24, 0.22, 0.28, 0.36, and 0.32 with a mean value of 0.28.

It is argued that the probability level at Digernessundet is equal to that of Sola. The monthly variation is, however, an average between the two stations. The calculated probabilities at Digernessundet thus are 0.16, 0.14, 0.17, 0.25, and 0.19, respectively, in the months November, December,..., March, with a mean value of the whole winter season of 0.18. The level of these probabilities is rather unprecise, but the probability is significantly higher (1% significance level) in February and significantly lower in December (3% level) than the mean value.

We have also given probabilities for some other events at Digernessundet:

PROBABILITIES DIGERNESSUNDET	NOV	DEC	JAN	FEB	MAR	MEAN
P(355)$_D$	0.16	0.14	0.17	0.25	0.19	0.18
P(3)$_D$	0.21	0.19	0.22	0.30	0.23	0.23
P(55)3$_D$	0.78	0.72	0.76	0.83	0.83	0.78
P(5)5$_D$	0.80	0.77	0.79	0.84	0.83	0.80

P(355) : The probability for 3 days with FX $\leq$ 3 the first day and FX $\leq$ 5 the following two days.

P(3) : The probability for 1 day with FX $\leq$ 3.

P(55)3 : The probability for 2 days with FX $\leq$5, if FX $\leq$ 3 the day before.

P(5)5 : The probability for 1 day with FX $\leq$ 5, if FX $\leq$ 5 the day before. By calculating P(5)5 we have used a statistical method, that is based on an application of Markov-chains.

1. INTRODUCTION.

The background for this report is a request from Norsk Hydro A/S concerning operational criteria in Digernessundet. A seasonal probability of periods which obey certain criteria is wanted, the season being November - March. The criteria are as follows: The maximum 10 min wind speed shall not exceed 5 ms^{-1} the first day, and 10 ms^{-1} the following two days.

Our institute have earlier this year made a report concerning extreme wind conditions at Digernessundet (1). Wind registrations from Digernessundet during a period of nearly two years were compared with simultaneous registrations at Utsira, a freely exposed weather station at the coast. Transfer coefficients of strong wind events at different sectors were computed. To calculate extreme wind conditions, a homogenous data set of 23 years from Utsira were used. By using the transfer coefficients, extreme wind conditions were calculated at Digernessundet.

The problem of giving probabilities for periods with low wind speed, however, is quite different. The frequency of such periods varies very much from year to year. This is especially the case when monthly frequencies are concerned. Besides, it is a rather difficult task to compare two different stations during periods of low wind speed. In such periods local effects frequently dominate. Due to weak background pressure fields, these effects also varies more strongly according to parameters like surface temperature, stability of the air mass and so on. The connection between two stations situated some distance away from each other therefore is complicated. We therefore have to use a different technique.

2. DATA BASIS.

2.1. Locality. Weather stations in the area.

Digernessundet is situated in Western Norway in the southern part of Hordaland county. The sound between Bømlo and Stord branches off to Digernessundet in the southern part. Digernessundet is situated between the little island Føyno and Stord, and is directed ESE-WSW (Fig. 1). The sound is landlocked in the sector WSW-N-NE. In the sector ENE-SE there is a relatively large fjord bassin, with the islands Borgundøy, Fjelbergøy and Halsnøy. Towards S and SSW is Bømlofjorden. Thus Digernessundet has a relatively free exposition in the sector ENE-S-SW, and is more sheltered from the remaining sector.

It is only a few weather stations in the area which may be representative for Digernessundet, due to its location. That means that the distance to the coast line must be of a corresponding length.

Moreover the relatively free exposition at the weather stations should be from the same sectors as for Digernessundet. Now we consider maximum wind forces of light or moderate forces. Estimations of maximum wind forces between the hours of observation frequently are of poorer quality than the corresponding estimations at the regular hours of observation. We will therefore only make use of instrumental data. Thus the actual stations for this investigation are Sola, Rennesøy-Galta and Flesland.

2.2. Instruments and exposition.

Both Sola and Flesland are equipped with the anemometer type Fuess 90z. The anemograph is recording the instantaneous wind speed and wind direction and give in addition 10 minute mean wind speed. The anemometer height is 11 and 6 m above the ground, respectively. Before 1979 the anemometer height was 11 m at Flesland too.

At Sola the area around the weather station is entirely flat. The only obstacles are habitation in the surroundings. At Flesland the airport is situated in a rather rugged terrain with mountain ridges, hills and valleys. The anemometer was moved about 1500 m towards NNE in September 1979, from the western side of the runway to the east side of the northern part. After the removal the anemometer is more sheltered from the SE wind than earlier, due to terrain influence and a lower anemometer height.

Rennesøy-Galta was equipped with an anemometer, type MI 48/250, in January 1984. The station is situated on the northwest part of Rennesøy, in the midst of Boknafjorden, and in a distance from the fjord of about 1 km in the sector W-N-NNE.

2.3. Data series and homogeneity.

Sola and Flesland have data series from 1957. At Sola the anemometer position is unchanged through the period, apart from a minor moving in 1969 (10-12 m). The data are considered homogeneous for the period 1957-1985. At Flesland the recorded mean wind speed has decreased a little since the removal of the anemometer in proportion to earlier, but not so much that the results of this investigation should be seriously affected.

The weather station Rennesøy-Galta was established in october 1979. Thus the data series consist of 6 complete years with data, of which the first 4 years are based on estimated observations. At first we intended to compare those data to Sola, but the results showed that random errors had too high influence, the period was too short. All that could be said was that the mean wind speed during November - March was approximately 1B higher at Rennesøy-Galta.

3. METHOD AND RESULTS.

3.1. Method.

Our task is to find the probability for a 3 days period that have a maximum 10 minute wind speed, fx, not exceeding 5 ms^{-1} the first day and not exceeding 10 ms^{-1} during the following two days. Here a day means the 24 hours period from 19 to 19 o'clock local time. Maximum wind speed is stored in our data archives as Beaufort values, FX, before 1982. We must therefore use FX≤3 (fx≤5.1 ms^{-1}) and FX≤5 (fx≤10.8 ms^{-1}) as the criteria. The probability for such a 3 days period is here called P(355).

At first we will find the relative frequency, f(E), of occurrence of an event, E, by counting the number of successes and then divide with the total possibility for successes.

We have used a data programme that makes such countings (unfortunately for only the same event for the concerning period), where the result day by day is listed in a table, and where the relative frequency for 1 day with a given event is computed.

Example :
The total number of successes in one month are 2 less than number of days of that month. Suppose a period is looking like : 2363343323556. The numbers represent the daily maximum wind forces (Beaufort). Here the number of cases of 355 are 6. Further we suppose that the total number of cases during a period of 29 years is 150 in September. Then the relative frequency is f(355)=150/28x29=0.18.

Consequently we must do a manual counting of the cases when the event 355 has occurred. That work is based on two tables (mentioned above) with the events 3 and 5 Beaufort respectively. As a result we get the relative frequency of the event 355 for each month. We also notice that there may be large variations in number of cases from year to year. These variations has a random nature and the choice of data series may have great influence on the computations of relative frequency. That means that data series as long as 29 years are rather too short, when we shall interpret the relative frequency as a probability.

As known from the statistical theory the probability of an event is taken as the relative frequency of occurrence of that event when the number of observations is very large. For our problem we must use the relative frequencies as approximate probabilities. Nevertheless it is possible to give a valuation of the uncertainty in some of the results, where these probabilities are entered.

3.2. Results from Sola and Flesland.

At first we look upon the countings of successes at Sola and Flesland, and make some calculations. Later we shall use these results when valueing the conditions in Digernessundet. In Table 1 and 2 are presented the relative frequencies of different events and the frequency distribution of cases with the event 355 in the period concerned.

SOLA 1957-1985

	Nov.	Dec.	Jan.	Feb.	Mar.
f(355) ~ P(355)	0.16	0.13	0.17	0.27	0.17
f(3) ~ P(3)	0.21	0.20	0.22	0.32	0.20
f(55)3 ~ P(55)3	0.79	0.68	0.77	0.85	0.83
P(5)5	0.80	0.76	0.80	0.84	0.83
Range of successes with 355 in one month.	0-12	0-12	0-12	1-19	0-12
Number of years with :					
0 cases	3	6	5	0	1
1- 5 "	15	14	12	12	17
6-10 "	10	6	9	14	10
11-15 "	1	3	3	1	1
16-20 "	0	0	0	2	0
>20 "	0	0	0	0	0

Table 1. Some relative frequencies, f, interpreted as probabilities (see below) and the frequency distribution of the event 355 in the period 1957-85 at Sola.

P(355) : The probability for 3 days with FX ≤ 3 the first day and FX ≤ 5 the following two days.
P(3) : The probability for 1 day with FX ≤ 3.
P(55)3 : The probability for 2 days with FX ≤5, if FX ≤ 3 the day before.
P(5)5 : The probability for 1 day with FX ≤ 5, if FX ≤ 5 the day before. By calculating P(5)5 we have used a statistical method, that is based on an application of Markov-chains.

FLESLAND 1957-1985

	Nov.	Dec.	Jan.	Feb.	Mar.
f(355) ~ P(355)	0.24	0.22	0.28	0.36	0.32
f(3) ~ P(3)	0.29	0.26	0.32	0.39	0.35
f(55)3 ~ P(55)3	0.86	0.85	0.86	0.92	0.93
P(5)5	0.86	0.85	0.86	0.90	0.89
Range of successes with 355 in one month.	0-16	0-20	0-18	3-17	0-22
Number of years with :					
0 cases	1	2	3	0	1
1- 5 "	12	13	6	5	11
6-10 "	9	8	10	11	5
11-15 "	6	4	8	10	6
16-20 "	1	2	2	3	4
>20 "	0	0	0	0	2

Table 2. Some relative frequencies, f, interpreted as probabilities (see below) and the frequency distribution of the event 355 in the period 1957-85 at Flesland.
For explanation of symbols, see Table 1.

The calculations illustrate a noticeable difference between the probality levels of Sola and Flesland. The frequency of periods with low wind speed is higher at Flesland than at Sola in all of the 5 months (November - March).

The seasonal variation of periods with low wind speed at Sola and Flesland is approximately the same. The frequency of a 355 event (definition, see Table 1) is higher in February than in November - December. February is the only month with at least one event of 355, at Sola as well as at Flesland.

We now look at the problem of significance of the seasonal variations. To get closer to such a problem, we have carried out a T - test at the f(355) values. We then presume that the $X_1, X_2, \ldots\ldots, X_{29}$ are independent relative frequencies of 355 - values (as an example) for one single month in each of the 29 years. We also presume that these frequencies are normally distributed $N(\mu,\sigma)$, where μ is the mean value and σ is the standard deviation. The test parameter,

$$T_0 = \frac{(\bar{X} - \mu)\sqrt{n}\sqrt{(n-1)}}{\sqrt{\Sigma(Xi - \bar{X})^2}}$$

then is T - distributed (n-1), n=29.

We now postulate the null - hypothesis :

$$\mu = \mu_0$$

where μ_0 is the mean value of f(355) of the whole winter season (November - March). If $|T_0|$ is large, we will get a low probability for a correct null hypothesis, which means that f(355) of the actual seasonal month most probably deviates significantly from the average winter value. The probability for a correct null hypothesis is called the significance level of the test.

Results from a T - test performed on the 355 data from Sola and Flesland is shown in Table 3.

	SOLA				FLESLAND			
	STAND. DEV.	f(355)	T_0	$P(T>\|T_0\|)$	STAND. DEV.	f(355)	T_0	$P(T>\|T_0\|)$
NOV	0.141	0.160	-0.76	>10%	0.157	0.243	-1.44	9%
DEC	0.123	0.134	-1.99	3%	0.174	0.222	-1.92	3.5%
JAN	0.136	0.169	-0.44	>10%	0.174	0.282	-0.09	>10%
FEB	0.160	0.269	2.92	0.4%	0.164	0.356	2.35	1%
MAR	0.109	0.169	-0.55	>10%	0.231	0.320	0.82	>10%
$\mu_0=\Sigma f(355)/5$ = 0.1798					= 0.2846			

Table 3. Results from a T - test performed on the 355 data from Sola and Flesland. T_0 is a test parameter and $P(T>|T_0|)$ is the significance level of the test.

It should now be clear that there is higher probability for having a 355 period in February than in any of the other 5 months. This is significant at a 1 % level. Correspondingly, it seems clear that December has a lower probability for a 355 period than the average of all of the 5 winter months (3 % level). It should be stressed, however, that the December minimum is less pronounced than the February maximum.

To look for an explanation to such a distinct February maximum, we present Fig. 2, illustrating the seasonal variation of the northern hemisphere blocking. In a blocking situation a high pressure system blocks for low pressure systems usually coming in from south and west to western Norway. Fig. 2 illustrates a distinct maximum in February of such blocking events.

3.3. The conditions at Digernessundet.

Probability level.

Our intention is now to interpret the conditions at Digernessundet. From the tables of wind frequency (2) we find in 25% (Sola), and 23% (Flesland) of the time (November - March), that the wind speed > 3B in the sector 80 - 250^0 . Correspondingly, 13% (Sola), and 8% (Flesland) > 3B in the sector 260 - 70^0 .

The sector 80 - 250^0 is just the sector at Digernessundet which is freely exposed. This sector is more freely exposed at Sola than at Flesland. Due to the frequent wind of speed > 3B within that sector, it seems that the probability of periods with low wind speed at Digernessundet in November - March should be closer to Sola than to Flesland.

Extreme values of 10 min wind speed with return periods 2 - 100 years is calculated for Digernessundet (1), and Sola (3). The 2 year extremes (most precise estimates) at both places are found to be 21 ms^{-1}. This fact supports our belief in that the probability for periods with low wind speed is close to that of Sola. Still, however, this is a point of rather low precision.

Seasonal variation.

Digernessundet has a geographical location between Sola and Flesland (Fig. 1). It then seems reasonable that the seasonal variation within the period November - March of periods with low wind speed should be an average of the variation at those two stations. Since the monthly relative frequencies also are influenced of random effects, this performs another reason for averaging the variation at the two stations to give the monthly probabilities at Digernessundet.

In Table 4 we have shown how the averaging of the variation at the two stations Sola and Flesland is performed. At the first step we calculate the relation between the relative frequency f(355) of each month and the mean value of f(355) in November - March at both stations, S and F. This parameter is then averaged between the two stations for each month, to give 1/2(S+F).

The results above are multiplied with the average of the whole winter period (November - March) at Sola. These values can then be interpreteted as probabilities for periods with low wind speed at Digernessundet, $P(355)_D$. As mentioned, this corresponds to a probability level as given for Sola, and a seasonal variation averaged between that of Sola and Flesland.

PARAMETER	NOV	DEC	JAN	FEB	MAR	MEAN
SOLA, f(355)	0.1601	0.1344	0.1688	0.2668	0.1668	0.1798
$S = (MONTH./MEAN)_S$	0.890	0.748	0.939	1.484	0.939	
FLESLAND, f(355)	0.2426	0.2224	0.2818	0.356	0.3199	0.2846
$F = (MONTH./MEAN)_F$	0.853	0.782	0.990	1.251	1.124	
1/2(S+F)	0.872	0.765	0.965	1.368	1.032	
$P(355)_D = 1/2(S+F) \cdot (MEAN)_S$	0.16	0.14	0.17	0.25	0.19	

Table 4. Seasonal variation of the relative frequencies f(355) at Sola and Flesland (definition of 355, see Table 1). Calculation (see text) of the probabilities, $P(355)_D$ of the events 355 occurring at Digernessundet.

A corresponding procedure is made for the P(3), P(55), and P(5)5 (symbols, see Table 1) values. The results are shown in Table 5.

PROBABILITIES DIGERNESSUNDET	NOV	DEC	JAN	FEB	MAR	MEAN
$P(355)_D$	0.16	0.14	0.17	0.25	0.19	0.18
$P(3)_D$	0.21	0.19	0.22	0.30	0.23	0.23
$P(55)3_D$	0.78	0.72	0.76	0.83	0.83	0.78
$P(5)5_D$	0.80	0.77	0.79	0.84	0.83	0.80

Table 5. Probabilities for periods of low wind speed (see Table 1) at Digernessundet, Stord.

One should again be aware of that the probability of one day < 5.1 ms^{-1}, P(3), and of an event defined by a wind speed < 5.1 ms^{-1} the first day and < 10.8 ms^{-1} the following two days, P(355), all are significantly higher in February than the winter (November - March) mean value. Correspondingly, the December probabilities are significantly lower than the mean value.

One should also note that the probabilities P(55)3 and P(5)5 lie at the same level in March as in February. This is interpreteted in such a way that the persistence of periods with low wind speed is equally in the two months.

4. LIST OF REFERENCES.

(1) Andresen, L; Fikke, S; Harstveit, K; Sunde, A:
"Extreme wind in Digernessundet, Stord."
Rap. no. 17/86, DNMI/KLIMA 1986.

(2) Andresen, L:
"Monthly and annual frequencies of concurrent wind forces and wind directions in Western Norway and Trøndelag."
Climatological summaries for Norway,
DNMI, Oslo 1979.

(3) Fikke, S og Johansen, K:
"Nedstrandsfjorden. Extreme winds and waves."
Rap. no. 26/85, DNMI/KLIMA 1985.

(4) Lejenäs, H and Økland, H:
"Characteristics of northern hemisphere blocking as determined from a long series of observational data."
Tellus 35A, 5, 1983, pp 350 - 362.

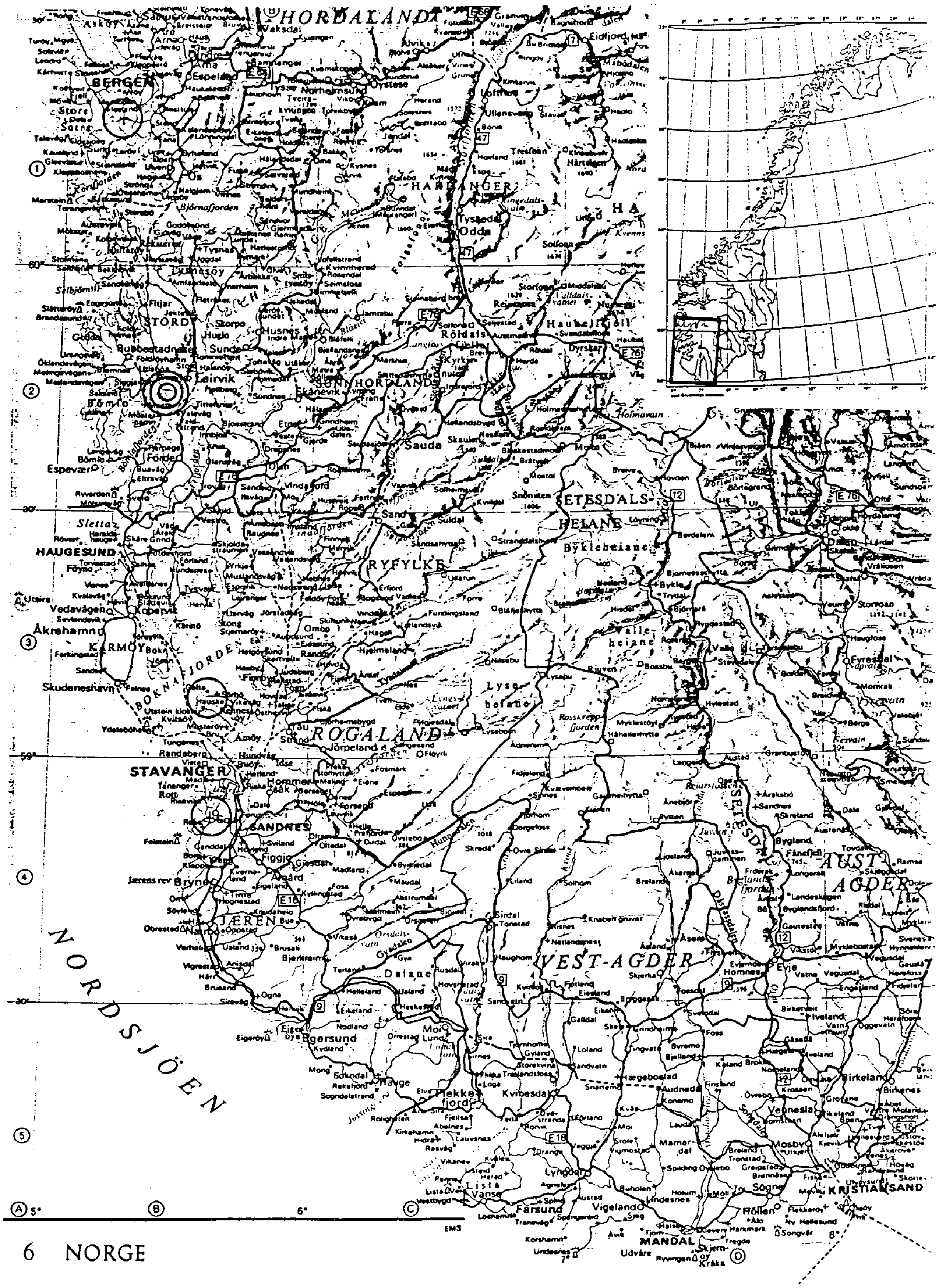

Figure 1. Map showing the location of Digernessundet and the actual weather stations for this investigation.

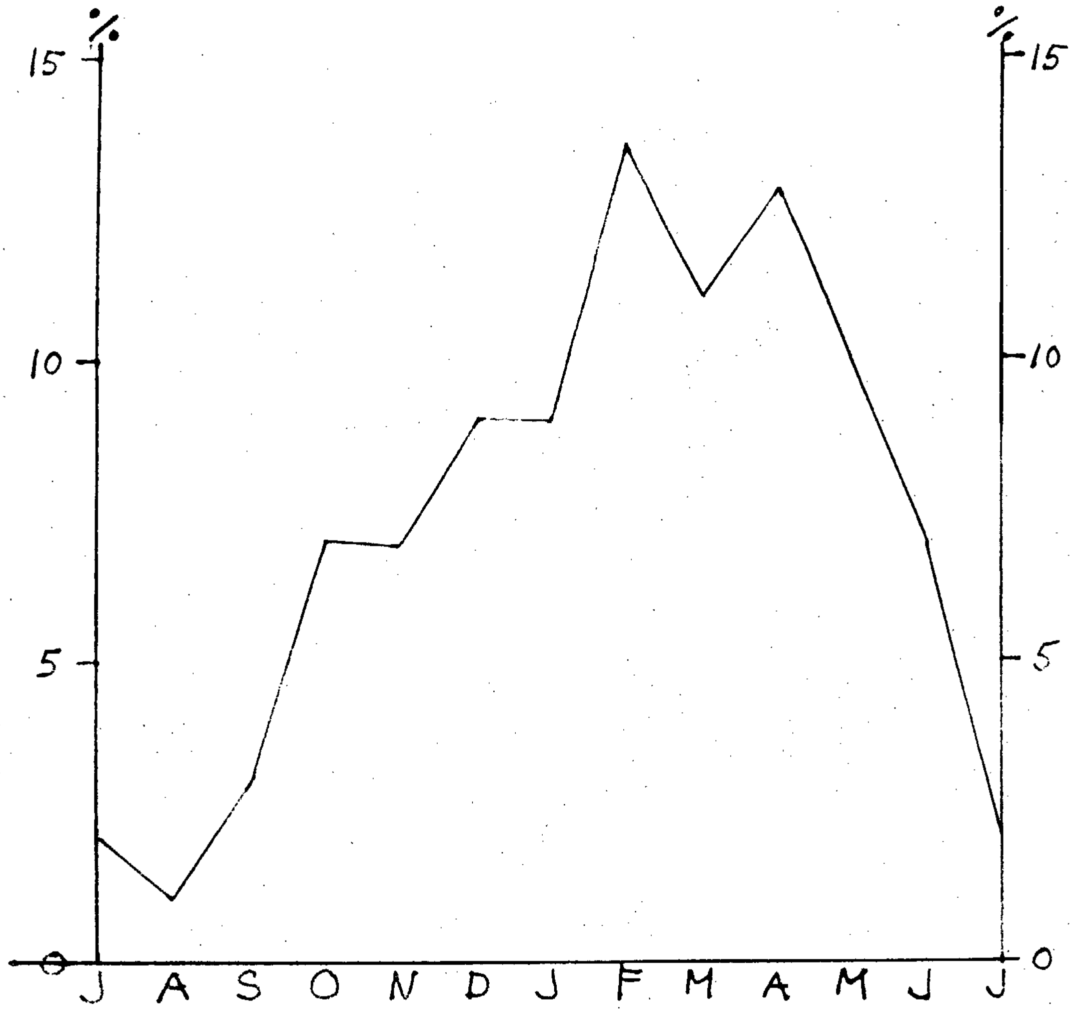

Figure 2. Monthly mean frequencies of blocking high, 1950-1979,
0^0 - Western Norway.
After Lejenäs and Økland (4).

DET NORSKE METEOROLOGISKE INSTITUTT

Norsk Hydro A/S
Oil and Gas Group
Oseberg Development Project
Boks 150
1324 LYSAKER

Deres ref.	Vår ref. (bes oppgitt ved svar)	Dato
	322.4/4112/86 SMF/ojo	30. september 1986

OPERASJONSKRITERIA FOR DIGERNESSUNDET, STORD.
PROSJEKTFORSLAG FOR BEREGNING AV SANNSYNLIGHER

Vi viser til møte med Deres Capt. Gerrit de Jong den 19. september. Etter Deres spesifikasjon ønskes det sannsynligheter for 72 timers perioder hvor vindhastighetene ikke overstiger:

a) 5 m/s for de første 24 timer
b) 10 m/s for de neste 48 timer

for Digernessundet, Stord, og for månedene november - mars.

Vi antar at det i første omgang er tilstrekkelig å utføre en slik analyse på våre værstasjoner Sola, Rennesøy - Galta og Flesland som grunnlag for et estimat av Digernessundet.

Denne analysen kan foretas av DNMI og vil eventuelt bli fakturert etter anvendt tid. Vi anslår at tidsforbruket og kostnadene vil bli av følgende størrelsesorden:

1.	Analyse av 3 værstasjoner, inklusive tilpasning av EDB-programmer:	50 timer
2.	Undersøke representativiteten for Digernessundet (skjønnsmessig, uten bruk av lokale data):	20 timer
3.	Rapport	30 timer
	Sum	100 timer

Arbeidet vil bli utført av en eller to av våre statsmeteorologer/forskere. Timeprisen er for tiden 300 kroner. Kostnadene vil da bli om lag:

100 timer à kr 300,-	=	kr 30.000,-
EDB-utgifter		" 6.000,-
	Sum	kr 36.000,-

Etter fullmakt

Bjørn Aune

Brev adresseres til Det norske meteorologiske institutt, ikke til funksjonærer.

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Kontoradresse: Niels Henrik Abels vei 40
Telegramadresse: Meteorologen Oslo 3
Telefon: (02) 60 50 90
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